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Ditching Requirements, Airbus Substantiation for the A320 and a Comparative Assessment of US Airways Flight 1549

Technical Note

(14 Pages)

Ditching Requirements, Airbus Substantiation for the A320 and a comparative assessment of US Airways Flight 1549

Technical Report

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SUMMARY:

This report contains a brief reminder of the relevant certification requirements for emergency landing and ditching , a summary of how Airbus showed compliance to these requirements for the A320 and finally a comparative assessment between the certification basis and the emergency landing of US Airways flight 1549.

The conclusions of this assessment can be summarized as follows:

- The rate of descent of US Airways 1549 was much higher than that assumed for the aircraft ditching certification (13 ft/s instead of 3.5 ft/s), leading to external pressures estimated to be greater than twice the certification values
- The damage to the aircraft is consistent with a high energy impact at the rear fuselage and the ensuing post impact motion through the water
- Despite the high vertical impact velocity and resulting damage to the aircraft, all occupants were protected from major injury and were able to evacuate the aircraft safely.

KEYWORDS	
RELATED DOCUMENTS	

	NAME	SIGLUM - FUNCTION	DATE & SIGNATURE
AUTHOR(S)		EDGLTC-Flight Physics	
		TBESRZ-Fuselage Specific Design	
APPROVAL		EDGLT-Flight Physics	
		EDSAZ-Structure	
AUTHORIZATION		GSE-Flight Safety	

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TABLE OF CONTENTS

1 CERTIFICATION REQUIREMENTS

Ditching FAR/JAR25 requirements cover the following three areas:

- Aircraft Behavior
- Structural Integrity and Occupant Protection
- Flotation Time

As a brief reminder, the following sections hi-light some of the most relevant parts of these requirements for this investigation.

1.1.1 Aircraft behavior

FAR/JAR 25.801(c)
“ The probable behavior of the airplane in a water landing must be investigated by model tests or by comparison with airplanes of similar configuration for which the ditching characteristics are know **“**

1.1.2 Structural integrity and occupant protection

FAR/JAR 25.561(a)
” The airplane, although it may be damaged in emergency landing conditions on land **or water**, must be designed as prescribed in this paragraph to protect each occupant under those conditions **“**

FAR/JAR 25.801(b)
” Each practicable design measure, compatible with the general characteristics of the airplane, must be taken **to minimize the probability** that in an emergency landing on water, the behavior of the airplane would cause immediate injury to the occupants or would make it impossible for them to escape **“**

FAR/JAR 25.801(e)
“ Unless the effect of the collapse of external doors and windows are accounted for in the investigation of the probable behavior of the airplane….the external doors and windows must be designed to withstand the probable maximum local pressure **“**

1.1.3 Flotation time

FAR/JAR 25.801(d)
“ It must be shown that, under reasonably probable water conditions, the flotation time and trim of the airplane will allow the occupants to leave the airplane and enter in the life rafts required by FAR/JAR 25.1415. If compliance with this provision is shown by buoyancy and trim computations, appropriate allowance must be made for probable structural damage and leakage **“**

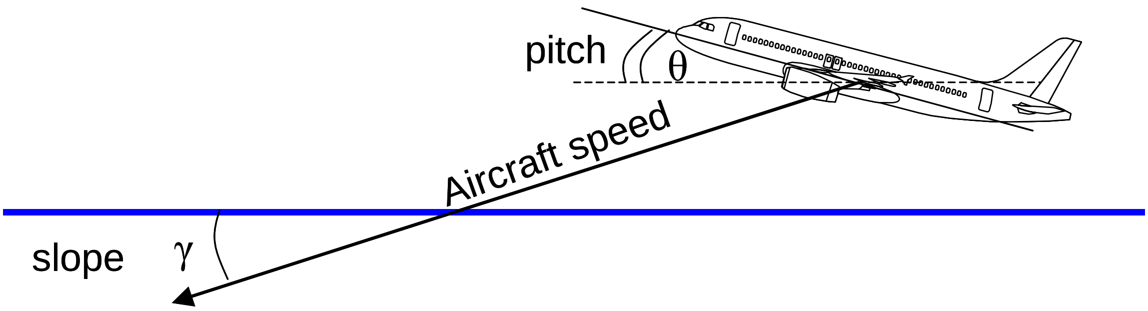
2 AIRBUS SUBSTANTIATION TO THE CERTIFICATION REQUIREMENTS FOR THE A320

2.1 Aircraft behavior – Compliance philosophy

The approach used by Airbus to investigate the overall behavior of the A320 was based on the extensive scale model testing performed on similar aircraft; i.e. the A300B2 and Mercure (see appendices 3.6-3.8 for a comparison of the aircraft geometry and some details on the scale models))

For the A300 B2 and the Mercure over 200 ditching tests were performed with scale models to identify the approach scenario (in terms of slope, pitch and speed) which gave the best overall aircraft behavior during ditching; i.e.

- No nose-diving or loss of aircraft control
- No brake-up of fuselage
- Minimum lower fuselage deformation



Based on the A300 B2 and Mercure test results and taking the similar geometry of the A320 into account, the following recommendations were derived for the A320:

- Landing gear retracted
- Full configuration for minimum speed or High Lift conf 3 when both engines fail
- pitch: $\theta \approx 11$ deg
- slope: $\gamma \approx -0.5$ deg

Note: a cross-check was performed which showed that these recommendations are in line with the test results published in NACA TN 2929 and NACA TR 1347(see appendix 3.9)

2.2 Structural integrity and occupant protection

2.2.1 Objective

To verify that design measures exist to give each occupant reasonable chance of escaping serious injury in emergency landing on water ensuring that, under the recommended airplane ditching conditions; i.e.

- The ditching accelerations do not exceed the crash accelerations of FAR/JAR 25.561
- The pressure and inertia loads shall not result in a global failure of the structure
- External doors shall withstand the local pressure (for floating capability)

2.2.2 Ditching inertia forces

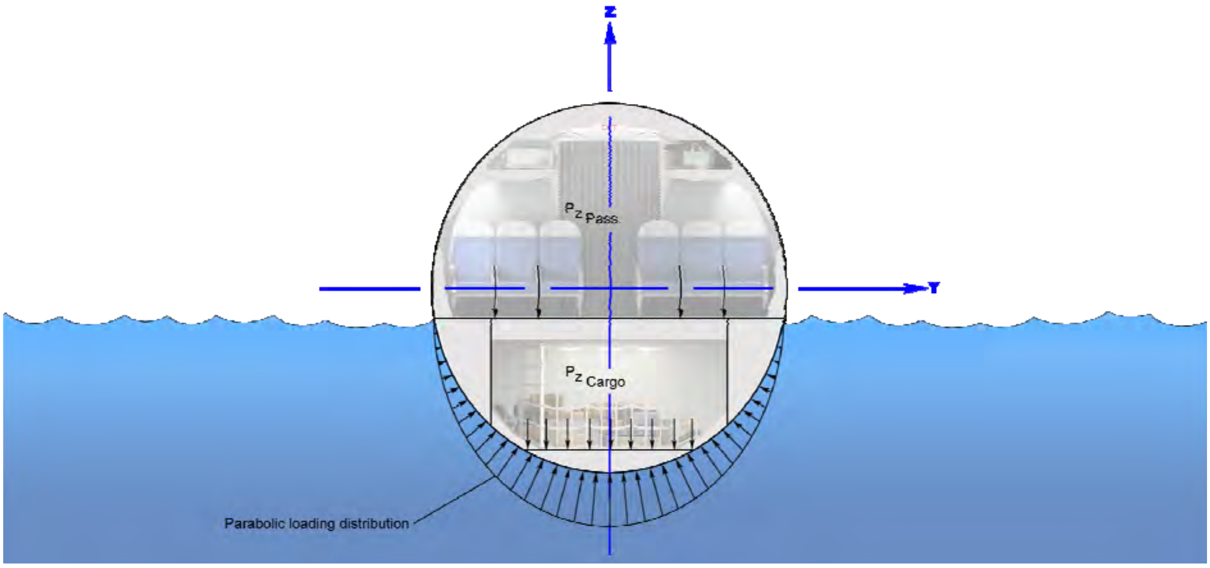
Methodology
Comparisons were made with the accelerations measured during tests with airplanes of similar configuration (A300 B2 and Mercure)
Results
The longitudinal and vertical accelerations measured in the tests were well below the values specified in JAR/FAR 25.561
The A320 which is designed to withstand the accelerations of JAR/FAR 25.561 is therefore able withstand the lower ditching accelerations

2.2.3 Water pressure loads

Methodology
The models used for the A300 B2 and Mercure ditching tests were calibrated such that the water pressure acting on the models could be derived from the deformation of the lower fuselage shell
Based on the water pressures from the above tests on similar aircraft, the water pressure for the A320 was calculated by means of a dimensional formula
Application
At the recommended pitch (11°), max landing weight, a slope of –1°(twice the recommended value) and for minimum aircraft speed, the corresponding average external pressures were calculated

2.2.4 Usage of the average computed pressures

Based on experience from tests on circular fuselage cross-sections a parabolic lateral distribution was assumed (p=0 at the sea-line and p=p_{max} on the bottom of the fuselage.)
For stress analysis these pressures were combined with inertia forces corresponding to the vertical acceleration



2.2.5 Certification strength justification

The external pressure and counteracting inertia loads were applied to a Finite Element Model of the aft fuselage
A static linear elastic analysis was performed with this model and the results were input into the Airbus frame analysis tool to calculate the reserve factors (see appendix 3.10)
All reserve factors were >1.0
Sufficient strength of the skin and stringers under the applied external pressure was demonstrated using analytical stress methods
Similarly sufficient strength of the cargo floor structure (crossbeams and support struts) was demonstrated using analytical stress methods
The loads applied to the passenger floor structure (crossbeams, seatrails, floor panels and support struts) are less than for other flight and ground cases (e.g. crash) and so the floor structure strength is covered by comparison
A separate finite element analysis was performed for the cargo door under external pressure and the subsequent strength analysis of the door itself and the door fittings demonstrated sufficient strength

2.2.6 Conclusions

The ditching tests on similar models have shown accelerations well below the accelerations prescribed in 25.561
Airbus has shown that the global structural integrity of the fuselage is ensured under water pressure loads and inertia forces resulting from an emergency landing on water at the recommended ditching conditions
For the same conditions, Airbus has shown adequate strength of the external doors

2.3 Flotation

2.3.1 Methodology

The theoretical investigation of the flotation capability was performed by the aid of the system tool AEROLIS to define the geometry (volumes, CG of the leaked water, water lines etc.)
The volume of the leaked water is computed by means of the following equation,

$$V_{WATER}(t) = \int_{t_0}^{t} q(t)dt = \int_{t_0}^{t} \mu A(t)\sqrt{2gh(t)}dt$$

where:

- *q(t)* is the water volumetric leakage flow
- V_{water} is the volume of the leaked water between the time t_0 and t
- μ is the coefficient of discharge
- *A(t)* is the leakage area
- *h(t)* is the water height acting on the leakage area

Conservatively, a roll angle of 5° (heeled over on the cargo door side) was assumed for this analysis

2.3.2 Results

This calculation gives a flotation time greater than 7 minutes.

2.3.3 Conclusions

Airbus has demonstrated a flotation time sufficient for airplane evacuation by buoyancy and trim computation
The leakages due to the dynamic and static water pressure actions have been taken into account in the computation

3 US Airways flight 1549 : a comparative assessment

3.1 A320 Certification basis versus US Airways flight 1549

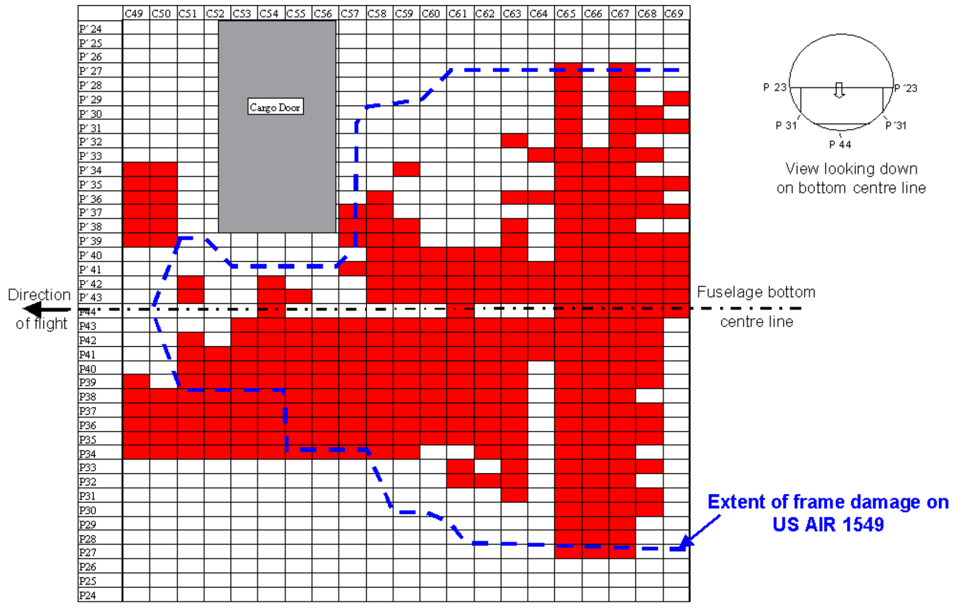
The table below shows a comparison of the certification basis versus the actual values for US Airways flight 1549

	Certification	US Airways1549
mass (kg)	66000	68500
pitch attitude (°)	11	9.5
aircraft speed (Kts)	118	125
glide slope (°)	-1	**-3.5**
sink rate (ft/ s)	3.5	**13**

The corresponding external pressures were estimated* and the reserve factors for the rear fuselage were calculated for this new load case **

**The estimation of this pressure required an extrapolation beyond the validated calculation range*
*** this analysis gives an estimate for the initial frame failures only, subsequent post-failure effects are not taken into account*

3.2 Frame Reserve Factors<1 (shown in red) for the external pressure estimated for the emergency water landing of flight 1549



3.3 Structural Engineering Assessment of US Airways 1549

The damage recorded on the aircraft is consistent with a high-energy impact at the rear fuselage and the ensuing post impact motion through the water
The damage increases progressively from no damage at C47 through sub-cargo floor crushing from frames C50-C56, large sub-passenger floor deformations up to C60 and finally disintegration of the lower panels aft of C60, including loss of the lower portion of the rear pressure bulkhead (C70)
The impact itself at 13 ft/s would be sufficient to cause large-scale collapse/failure of the fuselage frames, cargo floor, and passenger floor struts and initiate cracking of the lower fuselage skin.
Subsequent water ingress and post impact pressure and suction forces would be sufficiently destructive to cause the remaining damage (e.g. lower fuselage panel and rear pressure bulkhead partial loss/failure)

3.4 Conclusions

The sink rate of US AIR 1549 was much higher than that assumed for the aircraft certification (13 ft/s instead of 3.5 ft/s), leading to external pressures acting on the fuselage estimated to be greater than twice the certification values

The damage recorded on the aircraft is consistent with such a high-energy impact at the rear fuselage and the ensuing post impact motion through the water

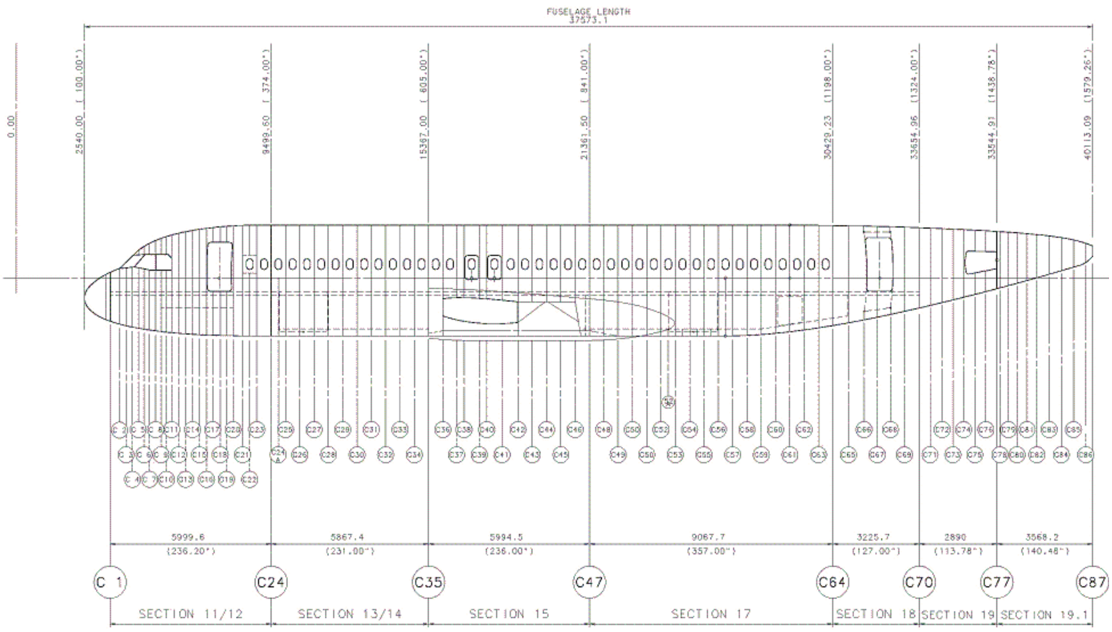
The overall behavior of the fuselage structure was excellent; i.e.

- The fuselage did not break-up on impact or post impact motion in the water, thus maintaining a safe, protective environment for the passengers
- The passenger doors, hatches and their surround structures remained undeformed, allowing the passengers to evacuate the aircraft safely
- The cabin floor retained its integrity, such that all passengers could evacuate the aircraft safely
- The remaining cabin retained its integrity; e.g. no items of mass or lining panels became detached, thus protecting the passengers from injury and allowing safe evacuation of the aircraft
- Much of the impact energy was absorbed by sub-passenger floor deformation allowing the passenger cabin to remain intact and reducing the acceleration levels experienced by the passengers.

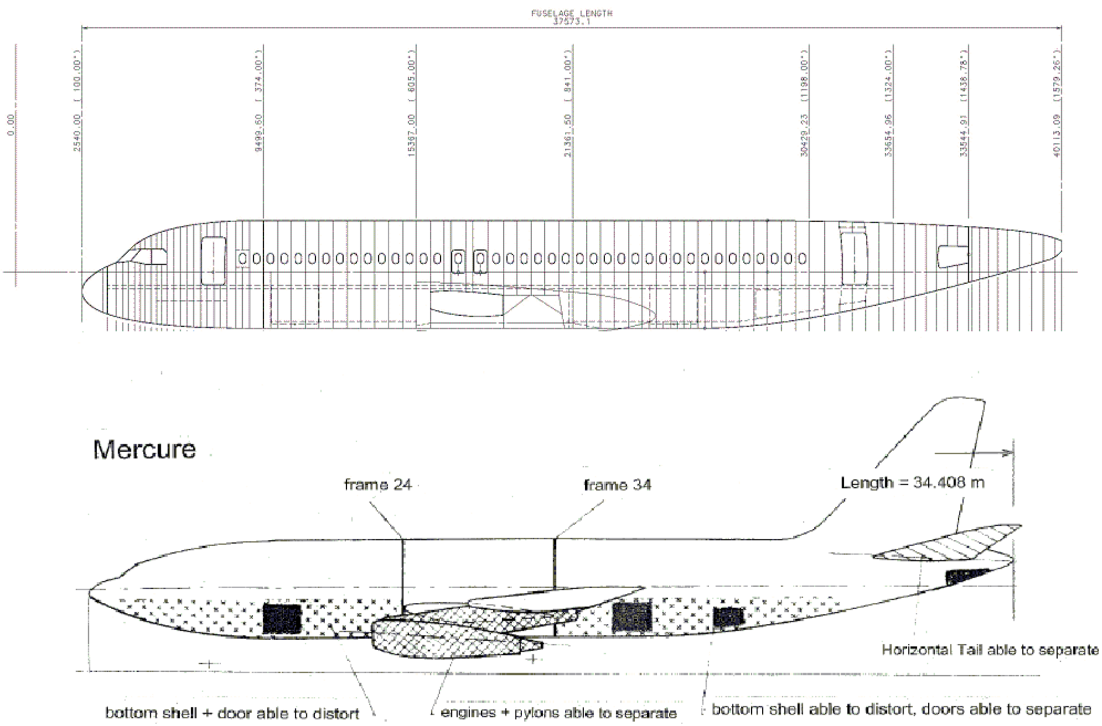
Despite the high vertical impact velocity and resulting damage to the aircraft, all occupants were protected from major injury and were able to evacuate the aircraft safely.

APPENDICES

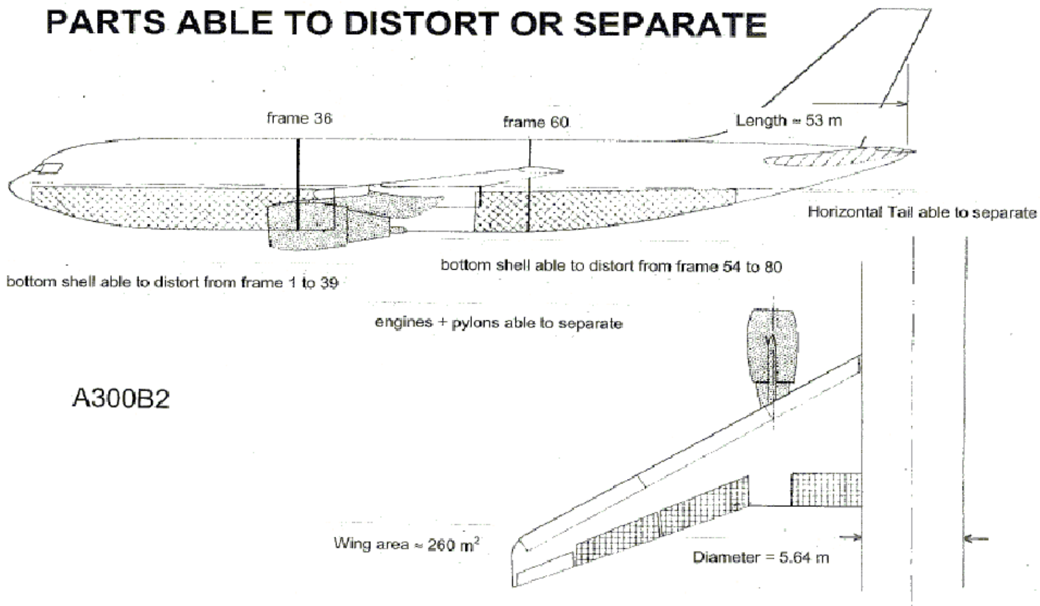
3.5 A320 Fuselage frame system



3.6 Comparison between A320 and Mercure fuselage geometry

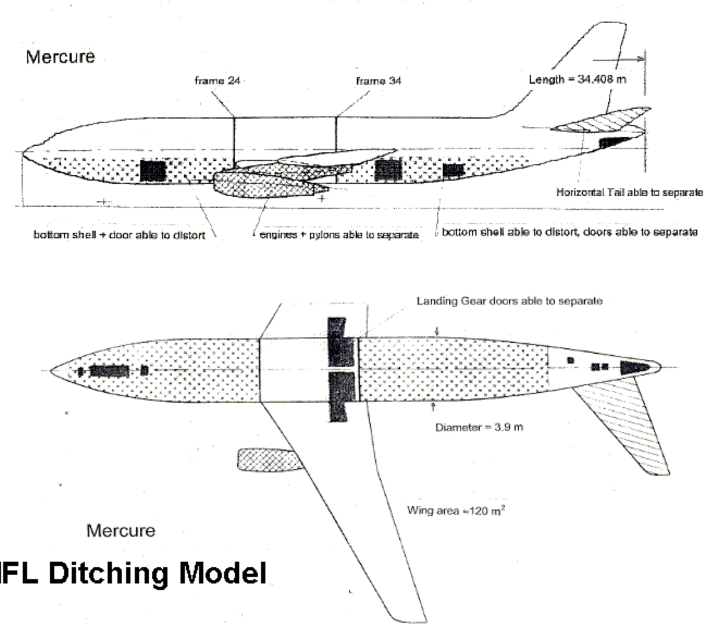


3.7 A300-B2 Scale model for ditching tests



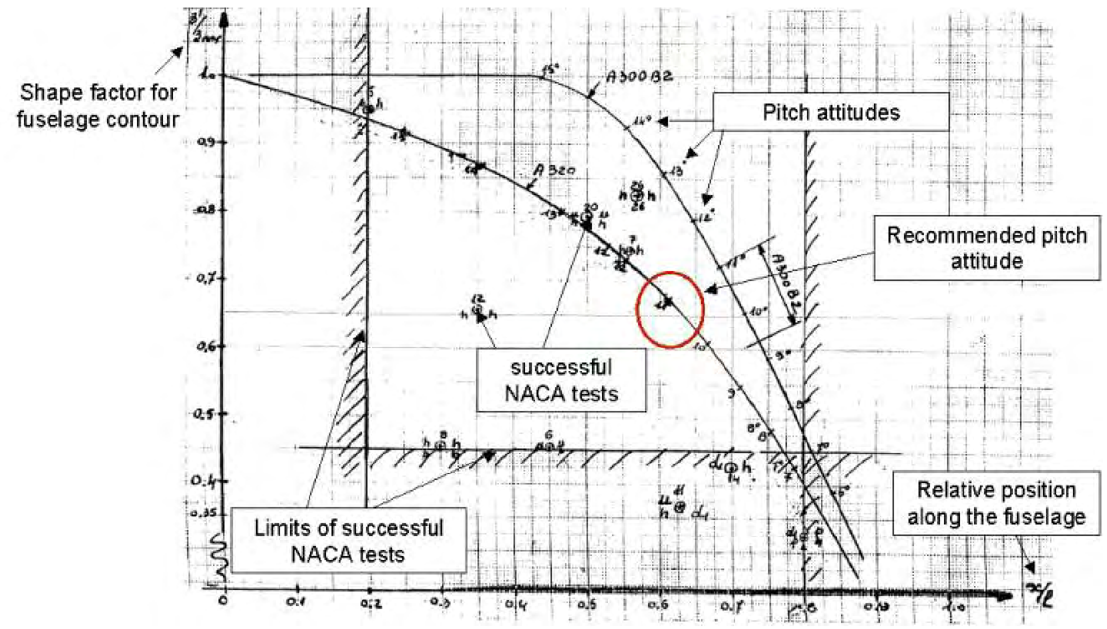
A300 – B2 IMFL Ditching Model

3.8 Mercure Scale model for ditching tests



Mercure IMFL Ditching Model

3.9 Typical usage of NACA TN2929 and NACA TR1347 for the verification of the recommended ditching conditions- pitch attitude



3.10 Fuselage frames RF plot (ditching certification loadcase)